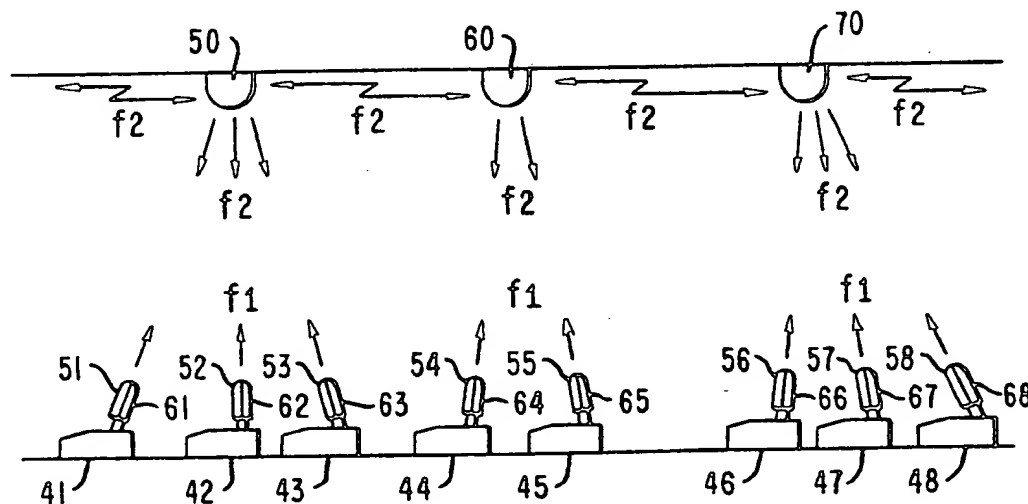




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁴ : H04B 9/00	A1	(11) International Publication Number: WO 89/ 06459 (43) International Publication Date: 13 July 1989 (13.07.89)
(21) International Application Number: PCT/US88/04544 (22) International Filing Date: 19 December 1988 (19.12.88) (31) Priority Application Numbers: 62/330401 269,823 (32) Priority Dates: 28 December 1987 (28.12.87) 9 November 1988 (09.11.88) (33) Priority Countries: JP US (71) Applicant: NCR CORPORATION [US/US]; World Headquarters, Dayton, OH 45479 (US). (72) Inventors: SARUTA, Makoto ; 50-404, Takamuradan-chi, 26 Takamura, Hiratsuka-shi, Kanagawa (JP). SUZUKI, Tatsuhiro ; 330-7, kosugayacho, Sakae-ku, Yokohama-shi, Kanagawa (JP).		(74) Agents: SESSLER, Albert, L., Jr. et al.; Law Department, Intellectual Property Section, NCR Corporation, World Headquarters, Dayton, OH 45479 (US). (81) Designated States: DE (European patent), FR (European patent), GB (European patent). Published <i>With international search report.</i>

(54) Title: OPTICAL WIRELESS DATA COMMUNICATION SYSTEM



(57) Abstract

An optical wireless data communication system includes a plurality of terminals (41-48) each having a transmitter (51-58) which transmits optical pulse signals at a first carrier frequency (f_1) and a receiver (61-68) which receives optical pulse signals on a second carrier frequency (f_2), and a plurality of optical repeaters (50, 60, 70) each having a plurality of transmitters (74, 80, 82), a plurality of receivers (72, 76, 78) and an optical signal path determining structure (84), the optical repeaters (50, 60, 70) being coupled to communicate with each other and with associated terminals (41-48). Each of the optical repeaters (60) converts the frequency of optical signals from an associated terminal (44, 45) to the second frequency (f_2) and transmits signals at the second frequency (f_2) to all the associated terminals (44, 45) and to all the other optical repeaters (50, 70) optically coupled thereto. Also, each optical repeater (60) transmits signals received from another optical repeater (50) to all the other repeaters (70) optically coupled thereto, except the transmitting repeater (50), and also transmits such signals to all the terminals (44, 45) associated therewith.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	ML	Mali
AU	Australia	GA	Gabon	MR	Mauritania
BB	Barbados	GB	United Kingdom	MW	Malawi
BE	Belgium	HU	Hungary	NL	Netherlands
BG	Bulgaria	IT	Italy	NO	Norway
BJ	Benin	JP	Japan	RO	Romania
BR	Brazil	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	LI	Liechtenstein	SN	Senegal
CH	Switzerland	LK	Sri Lanka	SU	Soviet Union
CM	Cameroon	LU	Luxembourg	TD	Chad
DE	Germany, Federal Republic of	MC	Monaco	TG	Togo
DK	Denmark	MG	Madagascar	US	United States of America
FI	Finland				

OPTICAL WIRELESS DATA COMMUNICATION SYSTEM

Technical Field

This invention relates to data communication systems of the kind including a plurality of terminals which are capable of transmitting and receiving optically coded data.

It should be understood herein that reference to "optical" and "light" include ultraviolet and infrared radiations as well as visible light.

The invention has a particular application to a system for transmitting data between a plurality of terminals, such as office computers and terminals thereof, point-of-sale (POS) terminals and other devices for in-house communication, which may be located in a large room or in a plurality of rooms, all of which devices are referred to herein as "terminals".

Background Art

From Patent Abstracts of Japan, page 131 E 362, abstract of Japanese Published Patent Application No. 60-140941 (Application Filing No. 251925/83), in the name of Fujitsu Ltd., there is known an optical space transmission system, wherein a plurality of terminal devices in the same or different rooms communicate via optical transmitters with transmission lines which are connected to a central controller. Data transmitted from a transmitting terminal is stored in the central controller and then transmitted simultaneously over all the transmission lines and via the optical transmitters to all the terminals, whereby a semi-duplex data transmission system is achieved.

One disadvantage of this known data communication system is that if the central control device becomes defective or inoperable then no data can be transmitted between the terminals of the system.

Disclosure of the Invention

It is an object of the present invention to provide a data communication system of the kind specified, wherein the aforementioned disadvantage is alleviated.

Therefore, according to the present invention, there is provided a data communication system of the kind specified, characterized in that said terminals include respective transmitters adapted to transmit optical signals with a first carrier frequency and respective receivers adapted to receive optical signals with a second carrier frequency through a first optical wireless communication channel, and by a plurality of optical repeaters each of which includes a plurality of transmitters, a plurality of receivers and path determining means adapted to determine the path of optical signals, the plurality of optical repeaters being connected so as to communicate optically with respect of said terminals by transmitting said optical signals through the first optical wireless communication channel and to communicate optically with each other by transmitting said optical signals through a second optical wireless communication channel, in that each said optical repeater converts the carrier frequency of optical signals from said first carrier frequency to said second carrier frequency to transmit said optical signals converted to said second carrier frequency from said transmitters incorporated therein to all associated terminals and to all of the other optical repeaters optically coupled thereto when said optical repeaters receives said optical signals with said first carrier frequency at a receiver therein from a terminal of the associated group of terminals through said first optical wireless communication channel, and in that each of said optical repeaters

transmits optical signals with said second carrier frequency from said transmitter incorporated therein to all associated terminals and to all of the other optical repeaters optically coupled thereto except the transmitting optical repeater of said optical signals with said second carrier frequency when said each of the optical repeaters receives at a further receiver said optical signals with said second carrier frequency from the optical repeater optically coupled to said further receiver through said second optical wireless communication channel.

A data communication system according to the present invention provides several advantages. Thus, no central control device is utilized and, furthermore, the terminals can readily be moved to alternative in-house locations, particularly since the system does not utilize any cable, optical fibers or like means to transmit data from one unit to another. A further advantage is that possible interference problems and errors resulting therefrom are minimized by using two distinct signal carrier frequencies and by inhibiting each repeater from retransmitting a received signal back to the repeater from which the received signal was transmitted.

Brief Description of the Drawing

One embodiment of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows the arrangement of an optical wireless communication system according to the present invention;

Fig. 2 shows the schematic structure of a repeater shown in Fig. 1;

Figs. 3A and 3B are block diagrams of a transmitter and a receiver of a terminal or like equipment;

Figs. 4A and 4B show the structure of the repeater shown in Fig. 1 and including the details of the path determining means; and

Fig. 5 shows waveforms of transmit and receive signals.

Description of the Preferred Embodiment

A preferred embodiment of the present invention will be described with reference to the arrangement and structure illustrated in Figs. 1 and 2. Fig. 1 shows the general arrangement of the optical wireless communication system according to the present invention. In the drawing, terminals 41, 42, 43, 44, 45, 46, 47, and 48 include transmitters 51, 52, 53, 54, 55, 56, 57 and 58 for transmitting optical pulse signals at carrier frequency f_1 (hereinafter referred to as f_1) and receivers 61, 62, 63, 64, 65, 66, 67 and 68 for receiving optical pulse signals at carrier frequency f_2 (hereinafter referred to as f_2). Each optical repeater 50, 60 or 70 is adapted to receive an optical signal f_1 from any of the terminals 41-48 associated therewith and to receive an optical signal f_2 from any of the other repeaters optically coupled thereto, and to transmit the optical signals to the other repeaters optically coupled thereto other than the repeater from which the optical signal was received, and to the terminals associated therewith.

Fig. 2 shows the general structure of a repeater 50, 60 or 70. As an example, the repeater 60 consists of a receiver 72 for receiving the optical signal f_1 from the terminal 44, a transmitter 74 for transmitting the optical signal f_2 to the terminal 44, a pair of receivers 76 and 78 for receiving the optical signals f_2 from the other repeaters 50 and 70, and a pair of transmitters 80 and 82 for transmitting the optical signals f_2 to the other repeaters 50 and 70. The repeater 60 also includes means, within the



- 5 -

dotted line and generally designated as 84, for determining the path of optical signals (hereinafter referred to as the determining means) and consisting of a pair of transmission forbidding signal generators 86 and 88, a pair of receive completion sensors 90 and 92, and a frequency converter 94.

In an explanation of the arrangement and structure illustrated in Figs. 1 and 2, it is now assumed that data is transmitted from terminal 44 to terminal 48. Terminal 44 transmits an optical signal at the carrier frequency f_1 from the transmitter 54 of the terminal 44 to the optical repeater 60. It is understood that while the details of the optical repeater 60 are mentioned in this portion of the description of the invention, the various elements 72-94, inclusive, are equally applicable to optical repeaters 50 and 70. The repeater 60 receives the optical signal f_1 at the receiver 72 thereof which signal is sent from the terminal 44. The optical signal at the carrier frequency f_1 thus received from transmitter 54 is converted into an electric signal to be sent to the frequency converter 94, which converts the electric signal thus received into an electric signal at the carrier frequency f_2 to be output to the transmitters 74, 80 and 82. The transmitters 74, 80 and 82 convert the electric signals at the carrier frequency f_2 into optical signals at the carrier frequency f_2 to be transmitted to the terminals 44 and 45 and to the repeaters 50 and 70.

Although the transmitter 74 of the repeater 60 sends the optical signals to the terminals 44 and 45, the carrier frequency f_1 of the optical signal which is transmitted from the transmitter 54 of the terminal 44 is different from the carrier frequency f_2 of the optical signal transmitted from the repeater 60 to such terminals 44 and 45, so that the signal transmitted from the terminal 44 does not interfere

with the signal transmitted from the repeater 60. Accordingly, the terminals 44 and 45 can correctly receive the signals at the carrier frequency f_2 transmitted from the repeater 60. However, it is to be noted that the data also is transmitted to the terminal 48, so that the terminals 44 and 45 simply confirm the address of destination in the received signals and will not receive the succeeding data. In this case, the system may be alternatively constructed such that only the terminal 44 which transmits the data to terminal 48 receives all the data from the repeater 60 and compares the data thus received with the data thus transmitted to see whether the data thus transmitted is correctly relayed via the repeater 60.

On the other hand, the optical signal at the frequency f_2 which is transmitted from the transmitter 82 of the repeater 60 to the repeater 70 is received by the receiver 76 of the repeater 70. The signal thus received by the receiver 76 is sent as an electrical signal to the frequency converter 94, to the transmission forbidding signal generator 86, and to the end of receive sensor 90. The transmission forbidding signal generator 86, upon receiving the electrical signal from the receiver 76, prepares a transmission forbidding signal to be output to the transmitter 80. The frequency converter 94 converts the electrical signal from the receiver 76 into the electrical signal at the frequency f_2 to be output to the transmitters 74, 80 and 82. The transmitter 82 converts the electrical signal at the frequency f_2 from the frequency converter 94 into an optical signal at the frequency f_2 to be transmitted to a repeater (not shown) located in a right-side position in Fig. 1. The transmitter 74 of the repeater 70 transmits the optical signal at the frequency f_2 to the terminals 46, 47 and 48. However, since the transmission forbidding signal has been output from

the transmission forbidding signal generator 86 to the transmitter 80, the transmitter 80 does not transmit any optical signal. As has been described above, the transmitter 80 does not transmit any optical signal to the repeater 60, so that an error in communication due to the interference of optical signals will not occur in the optical wireless communication between the repeaters 60 and 70. The electrical signal received from the receiver 76 is also sent to the end of receive or receive completion sensor 90. When the level of an electrical signal that is output from the receiver 76 is low for a predetermined period of time, the receive completion sensor 90 considers that the transmission is completed and stops outputting the transmission forbidding signal from the transmission forbidding signal generator 86.

The terminals 46, 47 and 48, respectively, receive the optical signal from the transmitter 74 of the repeater 70. However, the terminals 46 and 47 do not find addresses of their own in the destination address in the received signals, so that the terminals 46 and 47 do not receive the succeeding data. The terminal 48 confirms that the data which is transmitted thereto from the destination address is contained in the received signal and thus such terminal 48 receives all the data.

The optical signal at the frequency f_2 which is transmitted from the transmitter 80 of the repeater 60 to the repeater 50 is received by the receiver 78 of the repeater 50. The repeater 50 transmits the optical signals at the frequency f_2 from transmitter 74 to terminals 41, 42 and 43 and from transmitter 80 to a repeater (not shown) located in a left-side position in Fig. 1. However, it does not transmit the optical signal f_2 from its transmitter 82 which is adapted to transmit a signal to the repeater 60. Although the terminals 41, 42 and 43, respectively,

receive the optical signals f_2 from the transmitter 74 of the repeater 50, these terminals 41, 42 and 43 do not find their own addresses in the received signals, so that these terminals do not receive the succeeding data.

Next, a preferred embodiment of the present invention will be described in more detail with reference to the accompanying drawing. Figs. 3A and 3B show schematic structures of the transmitter 51 and the receiver 61 of the terminal 41 (Fig. 1). The description for terminal 41 along with the transmitter 51 and the receiver 61 thereof applies equally for the other terminals 42-48, the other transmitters 52-58 and the other receivers 62-68 (Fig. 1). The terminal 41 includes the transmitter 51 for transmitting the optical signal at the frequency f_1 , the receiver 61 for receiving the optical signal at the frequency f_2 from the repeater 50, and a transmit/receive controller (not shown). In this connection, data transmit/receive control by a transmit/receive controller is well known in the art, so that the description thereof is not included herein. Fig. 5 shows wave forms of signals at respective individual portions or areas of the terminal 41 and the optical repeater 50.

The transmitter 51 will be described in more detail with reference to Figs. 3A and 5. The transmitter 51 includes a modulator 100, a driver 102 and a light emitting element 104. In a signal transmitting operation, coded data in the shape of a square wave form (Fig. 5(a)) which is output from a transmit/receive controller (not shown) is modulated by the modulator 100 into a signal at the frequency f_1 , as shown as a voltage wave form in Fig. 5(b). The signal thus modulated is transmitted to the repeater 50 as an optical signal f_1 , shown as an intensity of light wave form in Fig. 5(c), from the light emitting element 104 which is driven by the driver 102.

Next, the receiver 61 of the terminal 41 will be described in more detail with reference to Figs. 3B and 5. The receiver 61 includes a light receiver or light receiving element 106, a first amplifier 108, a band pass filter 110 for selecting signals at the frequency f_2 , a second amplifier 112, an attenuator or automatic gain control circuit 114, a third amplifier 116 and a demodulator 118. The receiver 106 receives an optical signal f_2 which is transmitted from the repeater 50 as an intensity of light wave form shown in Fig. 5(d). In order to avoid the interference between the transmitted optical signals, optical pulse signals at different pulse frequencies f_1 and f_2 are employed, and it is preferable that these pulse frequencies are greatly different from each other. Accordingly, in this embodiment, it is preferred that $f_1 = 1.536$ MHz and $f_2 = 768$ KHz. The light receiver 106 converts the received optical signal f_2 into an electrical signal that is to be output to the first amplifier 108 which amplifies the electrical signal thus input to the first amplifier and to be output therefrom to the band pass filter 110. The band pass filter 110 selects only signals at the frequency f_2 and outputs an electrical signal, as shown as a voltage wave form in Fig. 5(e), to the second amplifier 112. The electrical signal which is amplified by the second amplifier 112 is output therefrom to the third amplifier 116 through the attenuator or automatic gain control circuit 114 in order to reduce distortion in the wave form. The electrical signal which is output from the attenuator or automatic gain control circuit 114 is amplified by the third amplifier 116 into a required magnitude and is output from the third amplifier to the demodulator 118 which codes the electrical signal received from the third amplifier 116 into a signal, shown as a voltage wave form in Fig. 5(g), to be output to a

transmit/receive controller (not shown) in the terminal 41 (Fig. 1). The signal transmitting/receiving operation is performed among the various terminals 41-48, inclusive, in the above mentioned manner.

Next, the structure of the optical repeater 60 and the individual operations associated with receipt of the optical signal, the frequency conversion of received signals, the designation of signal destination, and optical signal transmission will be described in more detail with reference to Figs. 4A and 4B. It should be noted that in the portions surrounded by broken lines, like numerals denote like parts, as indicated at 84 in Fig. 2.

The optical repeater 60 includes the receiver 72 (Fig. 4A) for receiving the optical signal f_1 from the terminal 44, the receivers 76 and 78 (Fig. 4B) for receiving optical signals f_2 from the other repeaters 50 and 70 and the transmitter 74 (Fig. 4B) for transmitting an optical signal f_2 which is wide in band and direction to the terminal 44. The optical repeater 60 also includes the transmitters 80 and 82 for transmitting optical signals f_2 which are relatively narrow in band and direction to the other repeaters 50 and 70, and the repeater 60 also includes the path determining means 84. The receiver 72 is constructed in almost the same manner as the receiver 61 (Fig. 3B) of the terminal 41 or the receiver 64 of the terminal 44 (Fig. 1), except that a band pass filter 111 and a demodulator 119 (Fig. 4A), which are somewhat different from those used in the terminals 41 or 44, are applied in the circuit because the frequency of light received at receiver 72 is different from that of the light received by receiver 51 of terminal 41 or of the light received by receiver 64 of terminal 44. The receivers 76 and 78 (Figs. 4A and 4B) are constructed in the same manner as the

receiver 61 (Fig. 3B) of the terminal 41 or the receiver 64 of the terminal 44 (Fig. 1). The transmitter 74 includes the driver 102 and a light emitting element 120 which is wide in band and direction. The transmitters 80 and 82 (Figs. 4A and 4B) each include an AND gate 122, a driver 102 and a light emitting element 124 which are relatively narrow in band and direction. The path determining means 84 includes the transmission forbidding signal generators 86 and 88, the receive completion sensors 90 and 92 and the frequency converter 94.

The transmission forbidding signal generators 86 and 88 each include a flip-flop 130. The flip-flop 130 is set at the rising of a received signal and outputs a transmission forbidding signal (when the signal is "low", the transmission is forbidden) from its Q/ (to be read as Q bar) terminal to the AND gate 122 of the transmitter 80 or 82 to forbid the transmission of the signal from the transmitter 80 or 82.

The receive completion sensors 90 and 92 each include an exclusive OR gate 132, a counter 134, an inverter 136 and an OR gate 138. When the signal receive operation by the receiver 76 or 78 is completed, only a "low" signal is output from the demodulator 118 of such receiver. The "low" signal from demodulator 118 is provided as one input to the exclusive OR gate 132. At that time, since the other input to the exclusive OR gate 132 (the Q output of flip-flop 130) is "high", the output of gate 132 will be "high" and hence the counter 134 commences the counting operation. The counter 134, after enduring this state for a predetermined duration of time, outputs a "high" signal when it completes a predetermined number of counts. The "high" signal output (D terminal) from the counter 134 is supplied to a reset input of the flip-flop 130 of the

- 12 -

transmission forbidding signal generator 86 via the inverter 136 and the OR gate 138 to reset the flip-flop 130. When the flip-flop 130 is reset, the transmission forbidding signal (Q/ output) is stopped ("high") to return the transmitter 80 or 82 to its initial state in which a signal can be transmitted.

The frequency converter 94 (Fig. 4A) consists of an OR gate 140, a counter 142 and an oscillator 144. In case no signal is received from any receiver, inputs of the OR gate 140 are "low" and hence the output thereof is also "low", so that the counter 142 is reset and a counting operation is not performed. Accordingly, a "low" signal is output from D terminal of the counter 142 to the AND gate 122 of each of the transmitters 80 and 82 and to the driver 102 of the transmitter 74 (Fig. 4B). When any one of the receivers 72, 76 or 78 receives a signal from another repeater or terminal, coded signals, shown as the square wave form in Fig. 5(g), are output from the demodulator 118 of receivers 76 and 78 or from demodulator 119 of receiver 72. The signals "high" and "low" thus output from demodulators 118 and 119 are supplied to the reset input of the counter 142 via the OR gate 140. The counter 142 performs the counting operation in accordance with clocks from the oscillator 144 only when the reset input thereof is "high". On the other hand, when the reset signal is "low", no counting operation is performed. Accordingly, when the signal, as shown in Fig. 5(g), is input to the reset input of the counter 142, a modulated signal, as shown in Fig. 5(f) and as an electrical signal at the frequency f_2 , is output from the output terminal D of the counter 142 and is supplied to the AND gate 122 of each of transmitters 80 and 82.

Next, the operation of the path determining structure 84 will be described in regard to Figs. 4A

and 4B. When a signal is transmitted from the terminal 44, the receiver 72 of the optical repeater 60 receives the optical signal f_1 to send a coded signal to the OR gate 140 in the same manner as a signal received by the receiver 64 of the above mentioned terminal 44. Then, the frequency converter 94 sends the electrical signal from the D terminal thereof at the frequency f_2 to the transmitters 74, 80 and 82, as has been described above. The transmitter 74, upon receiving the electrical signal at the frequency f_2 , transmits an optical signal f_2 from the light emitting element 120 to the terminal 44, the element 120 being driven by the driver 102.

Next, the case in which one repeater, as 50 (Fig. 1), receives the optical signal f_2 sent from another repeater, as 60 (Fig. 2), will be described. It is assumed that the receiver 76 of the repeater 60 receives the optical signal from the other repeater 50. The receiver 76 of the repeater 60, upon receiving the optical signal f_2 , sends the signal, as shown in the wave form in Fig. 5(g), to the OR gate 140 and to the transmission forbidding signal generator 86 (Fig. 4A). The frequency converter 94 outputs the electrical signal at the frequency f_2 from the output terminal D thereof in accordance with the signal sent to the OR gate 140 and the signal thus output is supplied to the transmitters 74, 80 and 82, as has been described above. The transmitter 74 (Fig. 4B), upon receiving the electrical signal f_2 , transmits the optical signal f_2 to the terminal 44, as has been described above. On the other hand, the transmission forbidding signal generator 86 (Fig. 4A) sends a "low" transmission forbidding signal from its Q/ terminal to the AND gate 122 of the transmitter 80 in accordance with the signal input into the transmission forbidding signal generator 86. Hence, no signal is transmitted from the transmitter 80 of

- 14 -

repeater 60 to the repeater 50 from which the signal has been transmitted. In addition, on this occasion, the receiver 78 (Fig. 4B) does not receive an optical signal from the other repeater 70, so that no transmission forbidding signal is output from the transmission forbidding signal generator 88. Accordingly, the transmitter 82 (Fig. 4B) sends an optical signal at the frequency f_2 to the next repeater in accordance with the electrical signal at the frequency f_2 from the frequency converter 94.

As has been described above, the data communication in optical signal form is performed among the optical repeaters 50, 60 or 70 without temporarily collecting communication data in a communication controller, by which an advantage can be obtained that the entire system can be prevented from being disabled due to the failure of a communication controller. In addition, the system is constructed such that one repeater does not transmit a received signal to another repeater which transmitted the signal, thereby reducing errors in communication.

CLAIMS:

1. A data communication system, including a plurality of terminals (41-48) which are capable of transmitting and receiving optically coded data, characterized in that said terminals (41-48) include respective transmitters (51-58) adapted to transmit optical signals with a first carrier frequency (f_1) and respective receivers (61-68) adapted to receive optical signals with a second carrier frequency (f_2) through a first optical wireless communication channel, and by a plurality of optical repeaters (50, 60, 70) each of which includes a plurality of transmitters (74, 80, 82), a plurality of receivers (72, 76, 78) and path determining means (84) adapted to determine the path of optical signals, the plurality of optical repeaters (50, 60, 70) being connected so as to communicate optically with respective groups of said terminals (41, 42, 43; 44, 45, 46, 47, 48) by transmitting said optical signals through the first optical wireless communication channel and to communicate optically with each other by transmitting said optical signals through a second optical wireless communication channel, in that each said optical repeater (e.g. 60) converts the carrier frequency of optical signals from said first carrier frequency (f_1) to said second carrier frequency (f_2) to transmit said optical signals converted to said second carrier frequency (f_2) from said transmitters (74, 80, 82) incorporated therein to all associated terminals (44, 45) and to all of the other optical repeaters (50, 70) optically coupled thereto when said optical repeaters (e.g. 60) receives said optical signals with said first carrier frequency (f_1) at a receiver (72) therein from a terminal (e.g. 44) of the associated group of terminals (44, 45) through said first optical wireless communication channel, and in

- 16 -

that each of said optical repeaters (e.g. 60) transmits optical signals with said second carrier frequency (f_2) from said transmitter (74, 82) incorporated therein to all associated terminals (e.g. 44, 45) and to all of the other optical repeaters (50, 70) optically coupled thereto except the transmitting optical repeater (e.g. 50) of said optical signals with said second carrier frequency (f_2) when said each of the optical repeaters (e.g. 60) receives at a further receiver (e.g. 76) said optical signals with said second carrier frequency (f_2) from the optical repeater (50) optically coupled to said further receiver (e.g. 76) through said second optical wireless communication channel.

2. A system according to claim 1, characterized in that transmitter (54) of each terminal (44) includes a modulator (100) adapted to receive coded data, and a light emitting element (104) responsive to said modulator (100) and adapted to transmit optical signals to the associated optical repeater (60).

3. A system according to claim 1, characterized in that the receiver (64) of each terminal (44) includes a light receiving element (106) adapted to receive an optical signal from the associated optical repeater (60), band pass filter means (108, 110) coupled to said light receiving element (106) and adapted to provide a filtered electrical signal, and a demodulator (118) adapted to demodulate said filtered original.

4. A system according to claim 1, characterized in that each of said optical repeaters (50, 60, 70) includes optical signal path determining means (84) having transmission forbidding signal

- 17 -

generator means (86, 88), receive completion sensor means (90, 92) coupled to said signal generator means (86, 88), and frequency converter means (94) coupled to the transmitters (74, 80, 82) included in the repeater (50, 60, 70) and adapted to generate electrical signals at said second carrier frequency (f_2).

1/5

FIG. 1

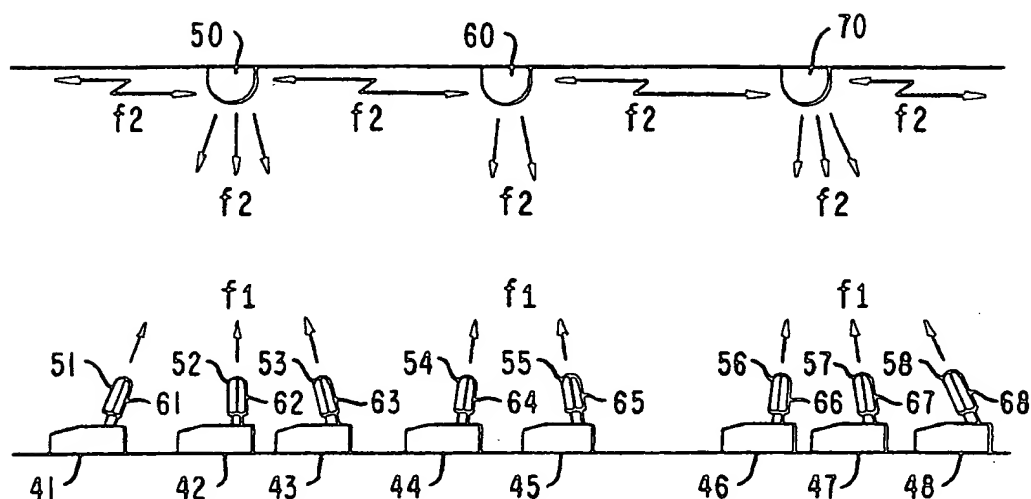
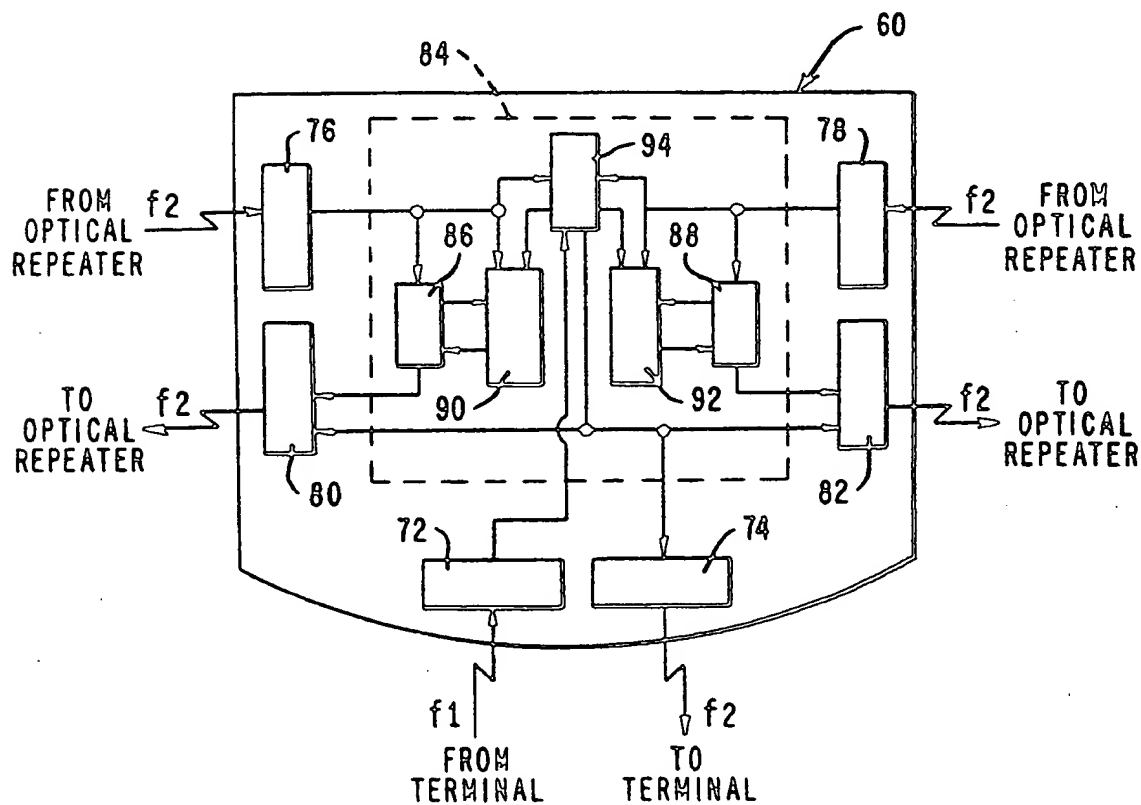
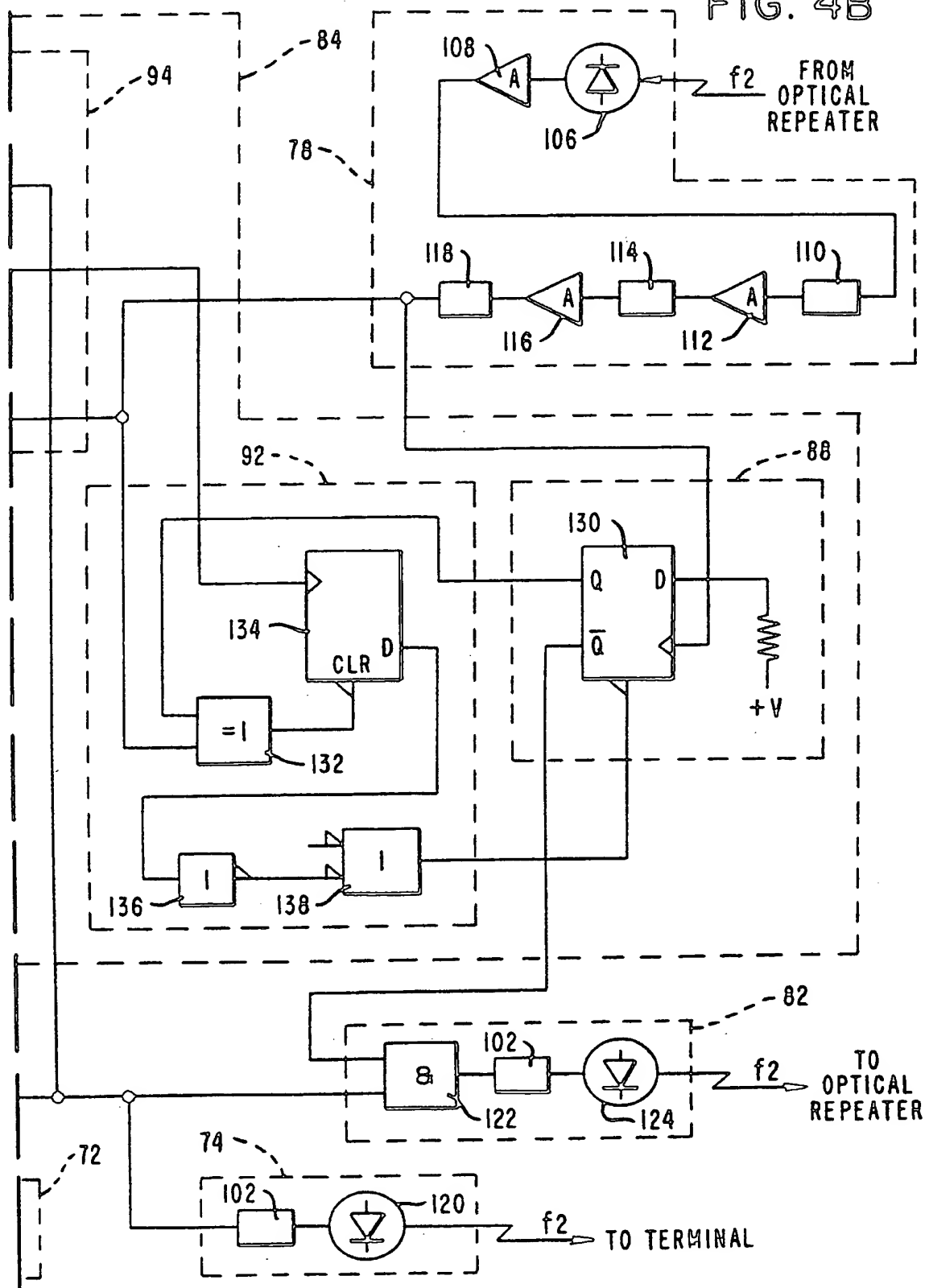


FIG. 2



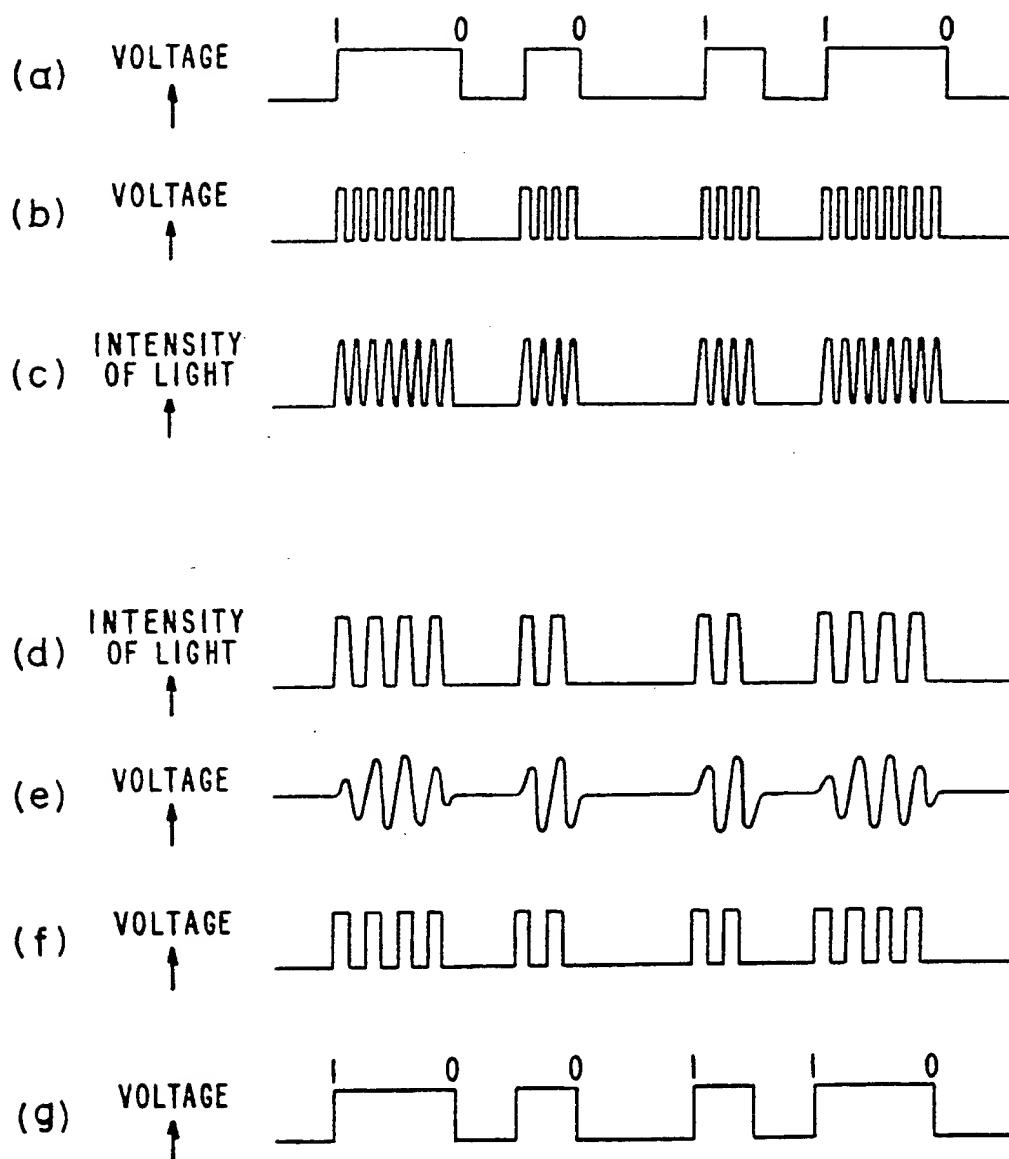
4/5

FIG. 4B



5/5

FIG. 5



2/5

FIG. 3A

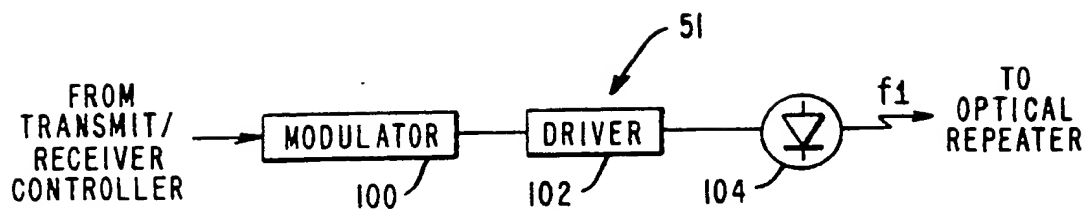
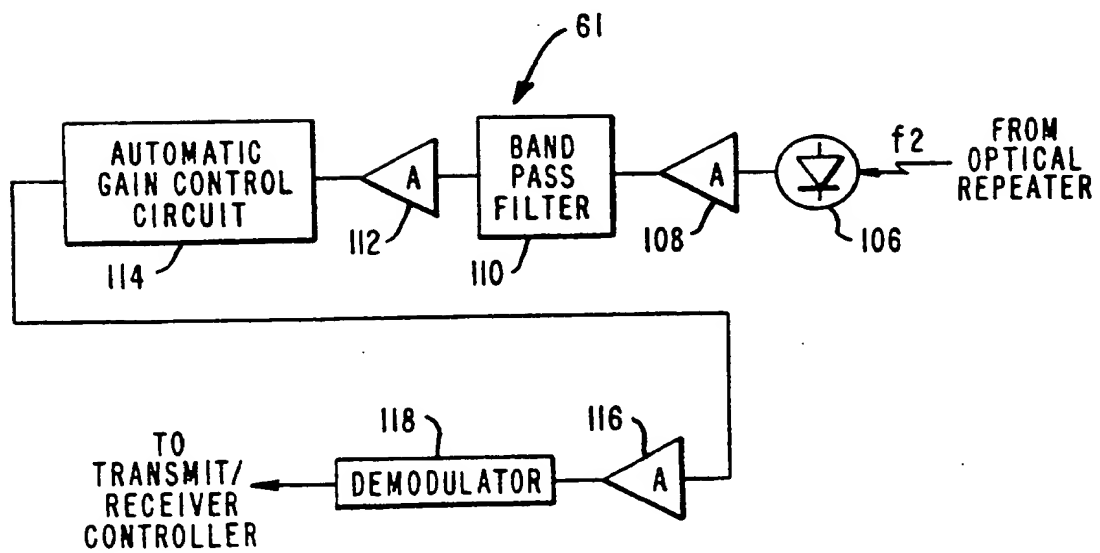
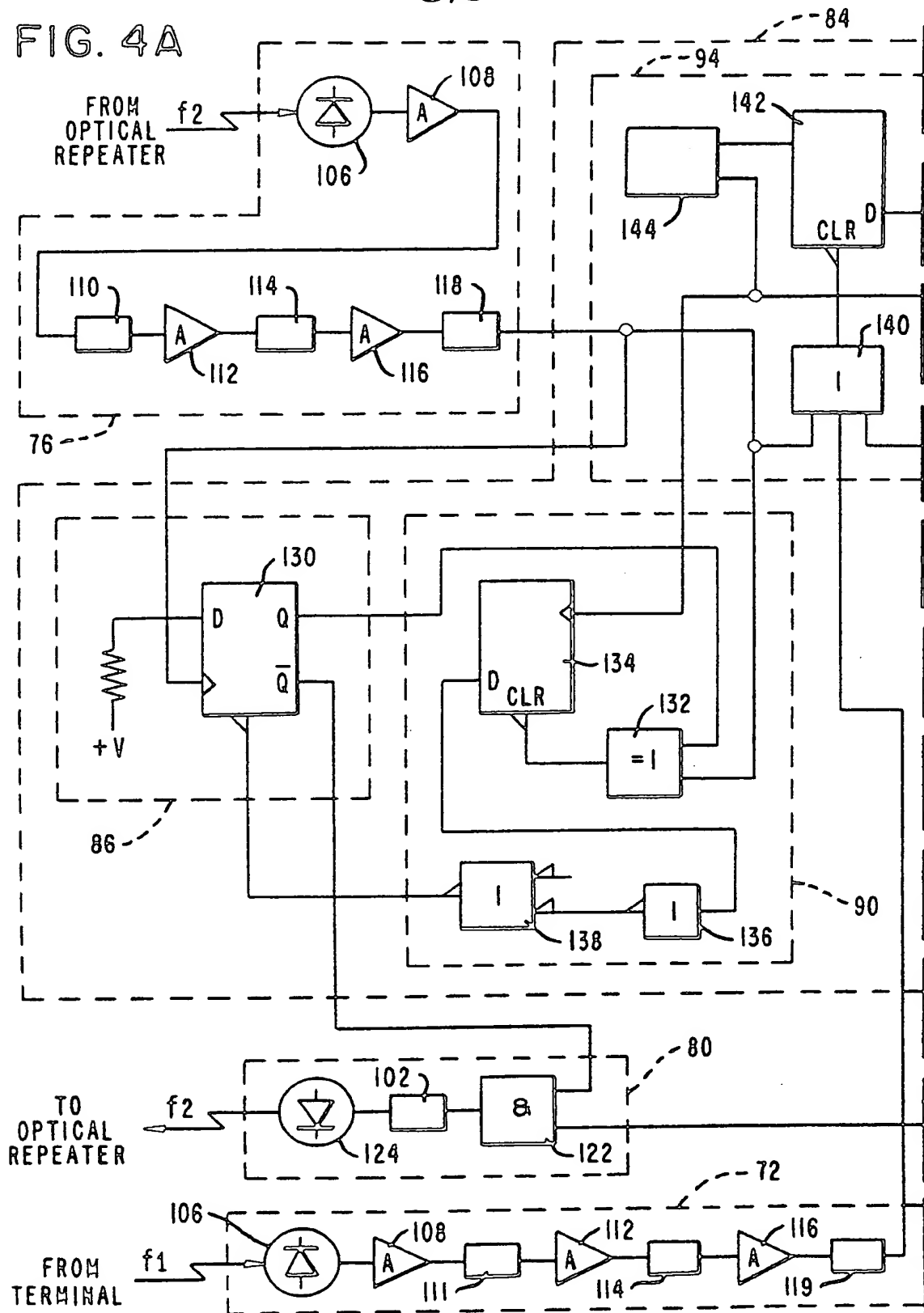


FIG. 3B



3/5

FIG. 4A



INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 88/04544

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁴ : H 04 B 9/00																										
II. FIELDS SEARCHED <div style="text-align: right; font-size: small;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; border: none;">Classification System ¹</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; vertical-align: top;">IPC⁴</td> <td style="border: none; vertical-align: top;">H 04 B; H 04 L</td> </tr> </table> <div style="text-align: center; font-size: x-small; margin-top: 10px;"> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸ </div>			Classification System ¹	Classification Symbols	IPC ⁴	H 04 B; H 04 L																				
Classification System ¹	Classification Symbols																									
IPC ⁴	H 04 B; H 04 L																									
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table style="width: 100%; border-collapse: collapse; font-size: x-small;"> <tr> <th style="width: 10%; border-bottom: 1px solid black;">Category ¹⁰</th> <th style="width: 70%; border-bottom: 1px solid black;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; border-bottom: 1px solid black;">Relevant to Claim No. ¹³</th> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">EP, A, 0091271 (MATSUSHITA) 12 October 1983 see page 6, line 24 - page 7, line 12; page 7, line 25 - page 8, line 9; page 10, line 16 - page 11, line 3</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="text-align: center; vertical-align: top;">--</td> <td style="text-align: center; vertical-align: top;">2-4</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">Y</td> <td style="vertical-align: top;">GB, A, 2187367 (RICOH) 3 September 1987 see page 2, lines 56-90; page 10, lines 92-100; claim 7</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="text-align: center; vertical-align: top;">--</td> <td style="text-align: center; vertical-align: top;">2-4</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">EP, A, 0196347 (IBM) 8 October 1986 see page 7, lines 11-30; page 8, line 27 - page 9, line 21</td> <td style="text-align: center; vertical-align: top;">2-4</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">EP, A, 0240119 (POLAROID) 7 October 1987 see claim 8</td> <td style="text-align: center; vertical-align: top;">3</td> </tr> <tr> <td></td> <td style="text-align: center;">--</td> <td style="text-align: center;">./.</td> </tr> </table>			Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	Y	EP, A, 0091271 (MATSUSHITA) 12 October 1983 see page 6, line 24 - page 7, line 12; page 7, line 25 - page 8, line 9; page 10, line 16 - page 11, line 3	1	A	--	2-4	Y	GB, A, 2187367 (RICOH) 3 September 1987 see page 2, lines 56-90; page 10, lines 92-100; claim 7	1	A	--	2-4	A	EP, A, 0196347 (IBM) 8 October 1986 see page 7, lines 11-30; page 8, line 27 - page 9, line 21	2-4	A	EP, A, 0240119 (POLAROID) 7 October 1987 see claim 8	3		--	./.
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³																								
Y	EP, A, 0091271 (MATSUSHITA) 12 October 1983 see page 6, line 24 - page 7, line 12; page 7, line 25 - page 8, line 9; page 10, line 16 - page 11, line 3	1																								
A	--	2-4																								
Y	GB, A, 2187367 (RICOH) 3 September 1987 see page 2, lines 56-90; page 10, lines 92-100; claim 7	1																								
A	--	2-4																								
A	EP, A, 0196347 (IBM) 8 October 1986 see page 7, lines 11-30; page 8, line 27 - page 9, line 21	2-4																								
A	EP, A, 0240119 (POLAROID) 7 October 1987 see claim 8	3																								
	--	./.																								
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>																										
IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> Date of the Actual Completion of the International Search <div style="text-align: center; font-size: large;">20th March 1989</div> </td> <td style="width: 50%; border: none; vertical-align: top;"> Date of Mailing of this International Search Report <div style="text-align: center; font-size: large;">27. 04. 89</div> </td> </tr> <tr> <td style="border: none; vertical-align: top;"> International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div> </td> <td style="border: none; vertical-align: top;"> Signature of Authorized Officer <div style="text-align: center;"> P.C.G. VAN DER PUTTEN </div> </td> </tr> </table>			Date of the Actual Completion of the International Search <div style="text-align: center; font-size: large;">20th March 1989</div>	Date of Mailing of this International Search Report <div style="text-align: center; font-size: large;">27. 04. 89</div>	International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: center;"> P.C.G. VAN DER PUTTEN </div>																				
Date of the Actual Completion of the International Search <div style="text-align: center; font-size: large;">20th March 1989</div>	Date of Mailing of this International Search Report <div style="text-align: center; font-size: large;">27. 04. 89</div>																									
International Searching Authority <div style="text-align: center; font-weight: bold;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: center;"> P.C.G. VAN DER PUTTEN </div>																									

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	EP, A, 0189273 (WESTINGHOUSE) 30 July 1986 see claims 1,8	3
A	Patent Abstracts of Japan, volume 7, no. 129 (E-179)(1274), 4 June 1983, & JP, A, 5844832 (MITSUBISHI DENKI K.K.) 15 March 1983 see abstract	3

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 8804544

SA 26142

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 18/04/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0091271	12-10-83	JP-A- 58170141	06-10-83
GB-A- 2187367	03-09-87	JP-A- 62210749	16-09-87
		FR-A- 2598575	13-11-87
		DE-A- 3700492	16-07-87
		JP-A- 62210748	16-09-87
		JP-A- 62160844	16-07-87
EP-A- 0196347	08-10-86	JP-A- 62042635	24-02-87
EP-A- 0240119	07-10-87	JP-A- 62209940	16-09-87
		US-A- 4759011	19-07-88
		CA-A- 1248588	10-01-89
EP-A- 0189273	30-07-86	JP-A- 61173537	05-08-86
		US-A- 4662715	05-05-87

THIS PAGE BLANK (USPTO)